



Potential public health impact, uncertainty and public policy

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Attributable fraction

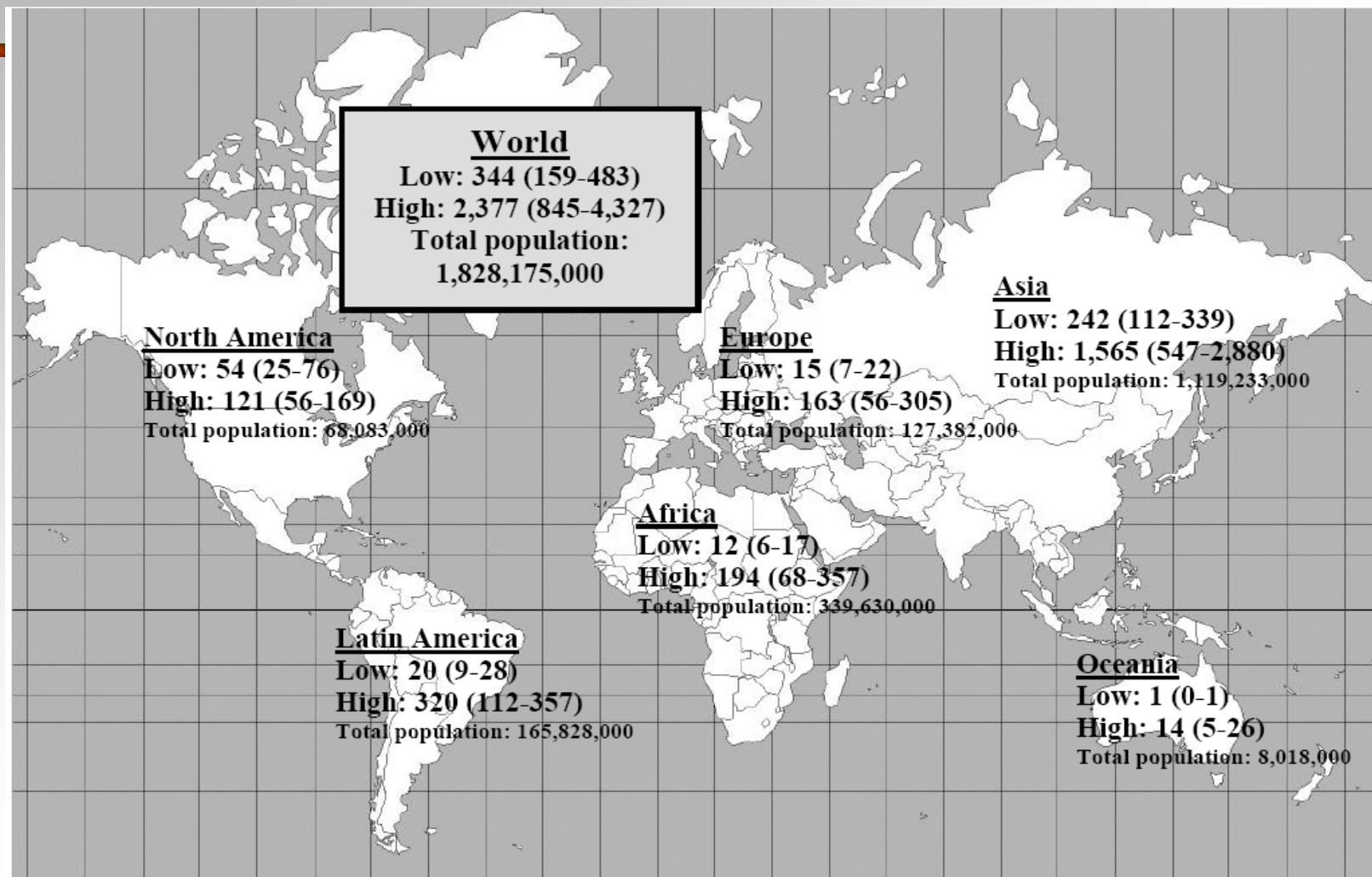
For case-control studies with adjusted odds ratios, a less biased formula is

$$AF_p = P_1(RR_a - 1)/RR_a$$

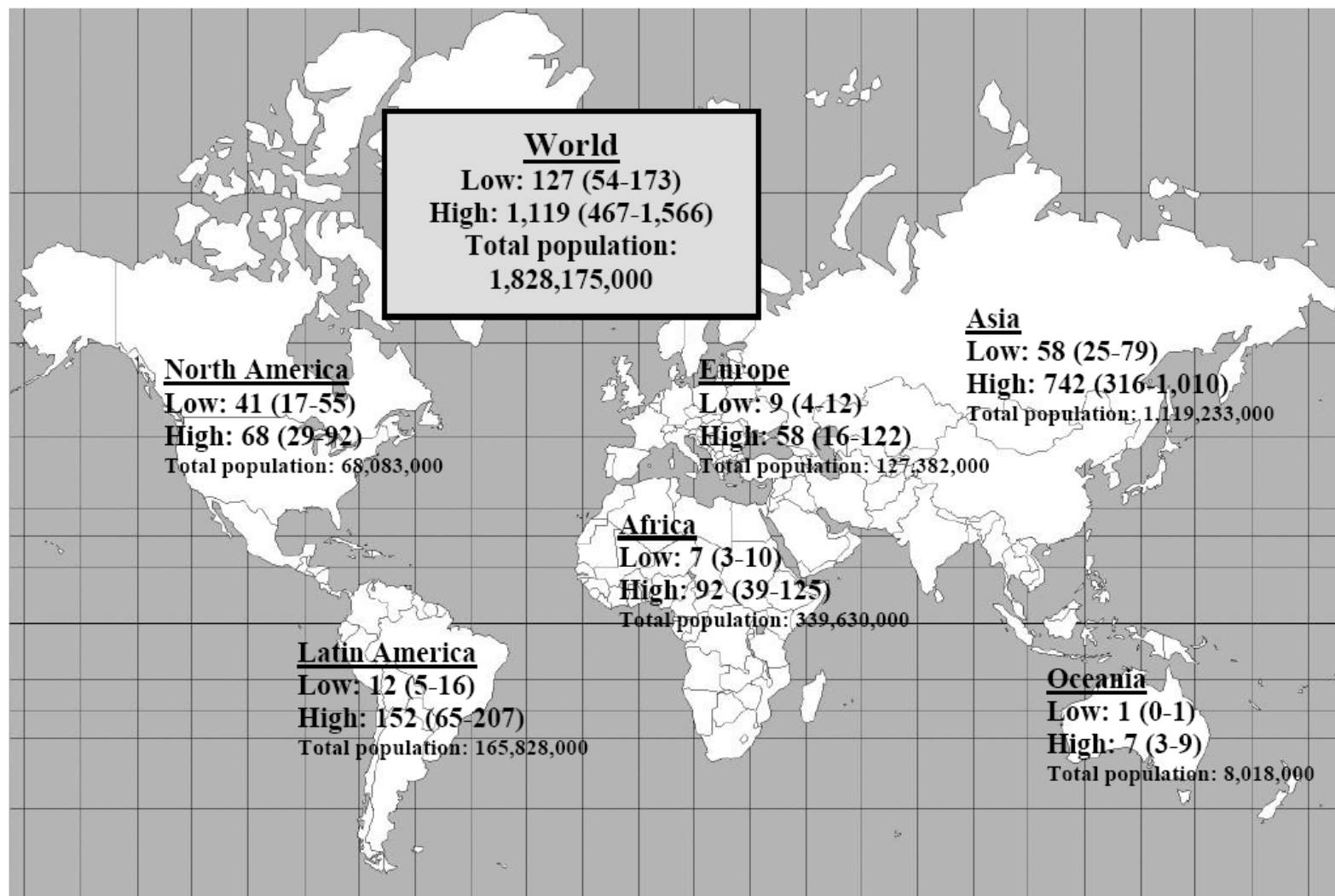
where RR_a is the adjusted rate ratio estimate

P_1 is the exposure prevalence among the cases in the target population.

Number of cases of leukemia under 14 possibly attributable to EMF arithmetic mean exposure above $0.3 \mu\text{T}$.

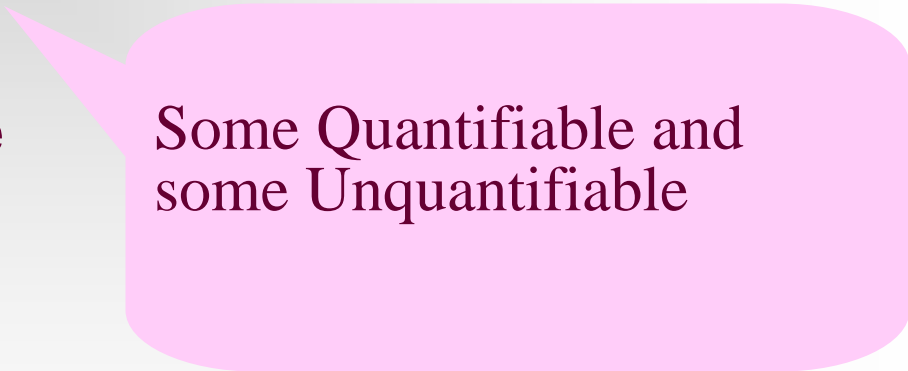


Number of cases of leukemia under 14 possibly attributable to EMF
geometric mean exposure above $0.4 \mu\text{T}$.



Uncertainties in the risk characterization

- Outcomes to consider
- Sources and contributions
- Exposure Metric
- Prevalence of high exposure
- Causality
- Magnitude of Risk
- Shape of dose-response



Some Quantifiable and
some Unquantifiable

Characterization of exposure

- Capturing relevant activities
 - Estimates of exposure from all sources
 - Estimates of relevant (lifetime?) exposure
 - Temporal variation
 - Errors in measurement
-

Personal exposure

Background field in home

Appliances in home

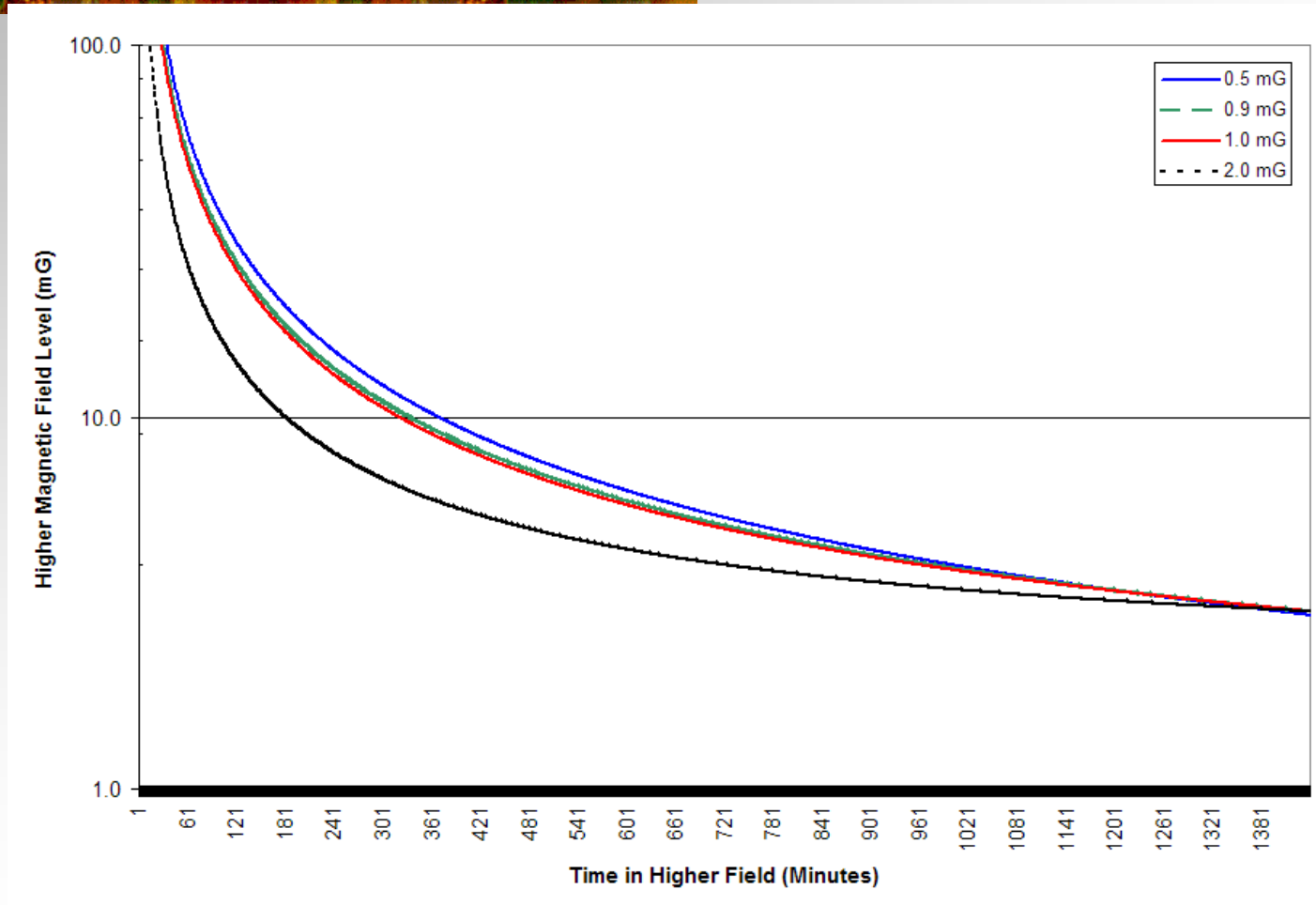
School

Elsewhere

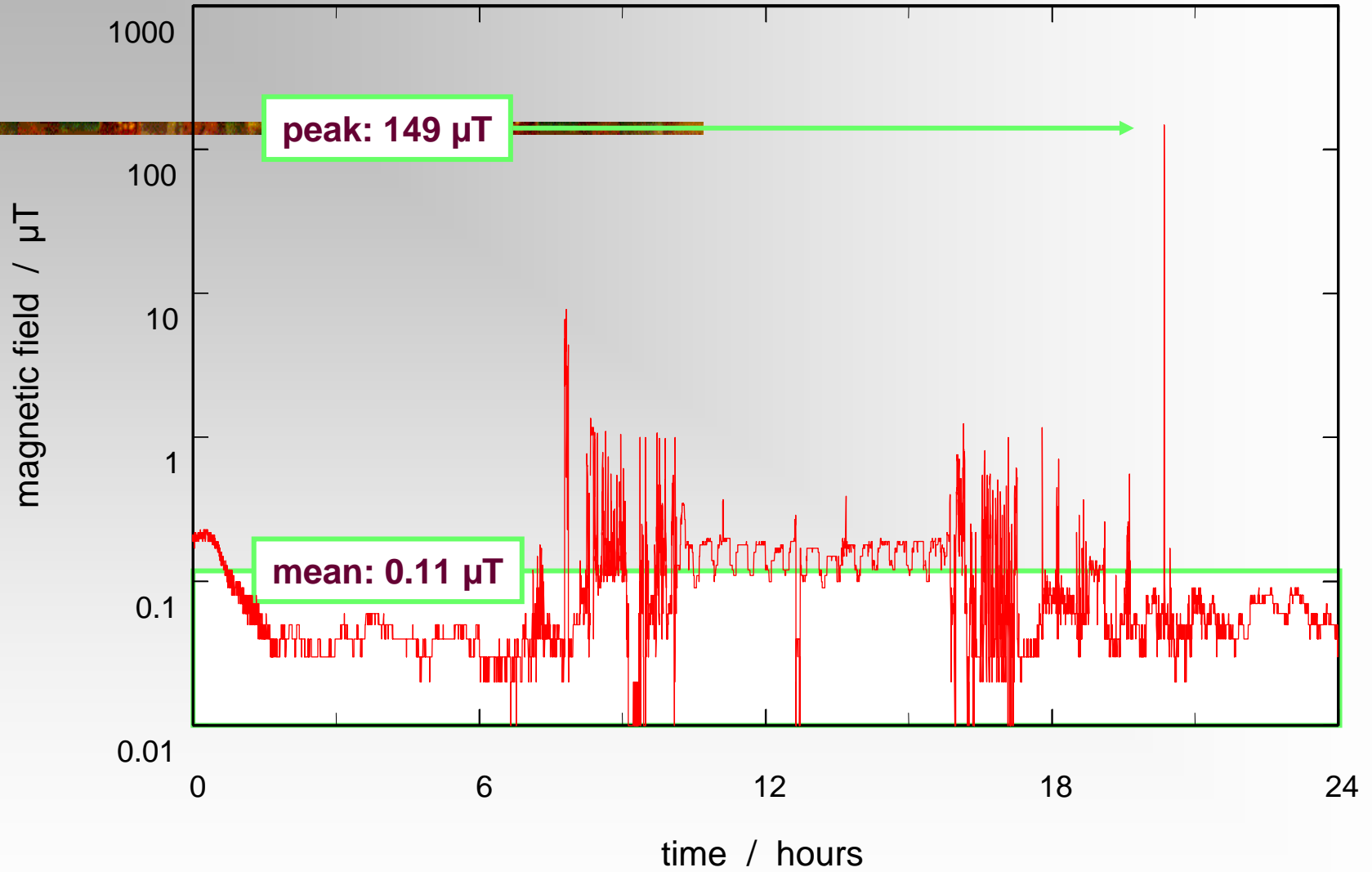
Our measurements of background field in home

Sources and contributions

Sources and contributions: Time in higher field in order to reach a 24-hour time-weighted-average exposure of $0.3 \mu\text{T}$.



Exposure Metric



Exposure Metric:

“Some other aspect of exposure”

- Threshold/peak/high fields
 - Polarisation
 - Waveform
 - harmonics, transients
 - Rate of change/intermittency
 - AC/DC
-

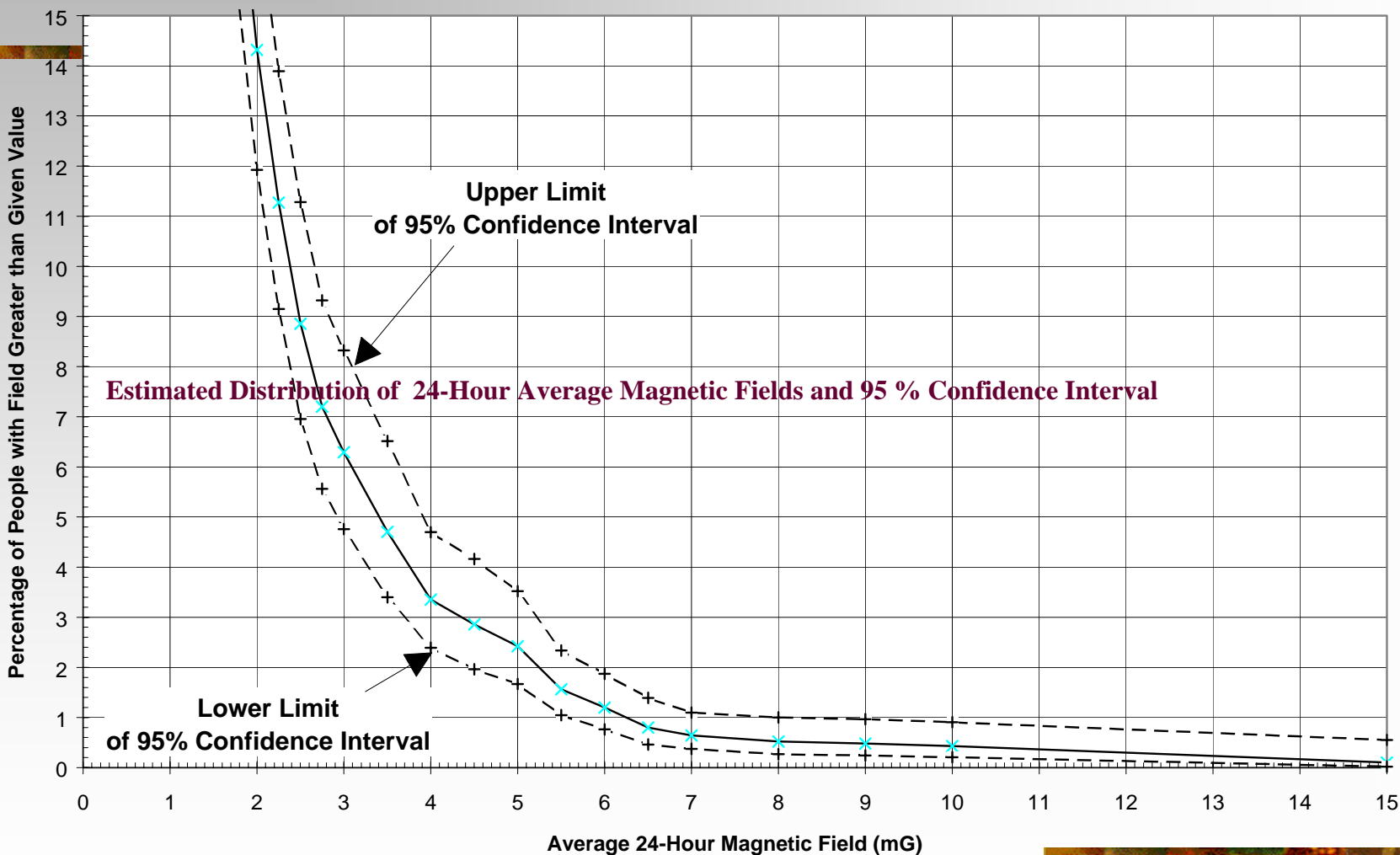
Exposure Metric: Related exposures

- **Power line specific**
 - characteristic of the field
 - SES/mobility/demographic
 - E-field
 - corona ions
- **Contact currents**

Prevalence of high exposure

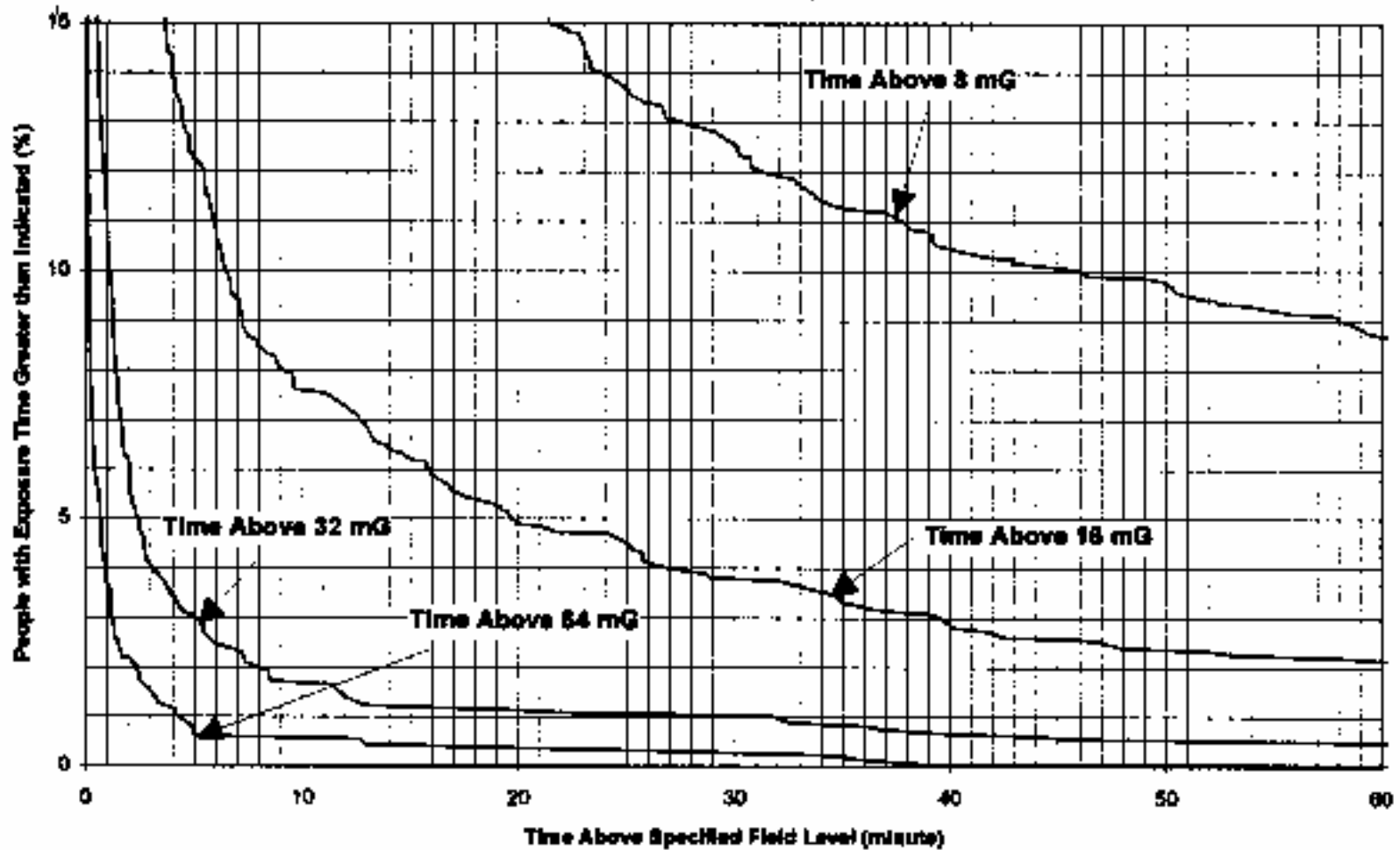
- Based mostly on Epidemiologic Studies
- Exposure Surveys in few countries
- Large Uncertainty
- Regional range is based on the lowest level and highest exposure levels from the countries in a given region. Where there was no information from any countries in the region, the lowest and highest exposure levels overall were used

Estimated Distribution of Average 24-Hour Magnetic Field and 95% Confidence Interval

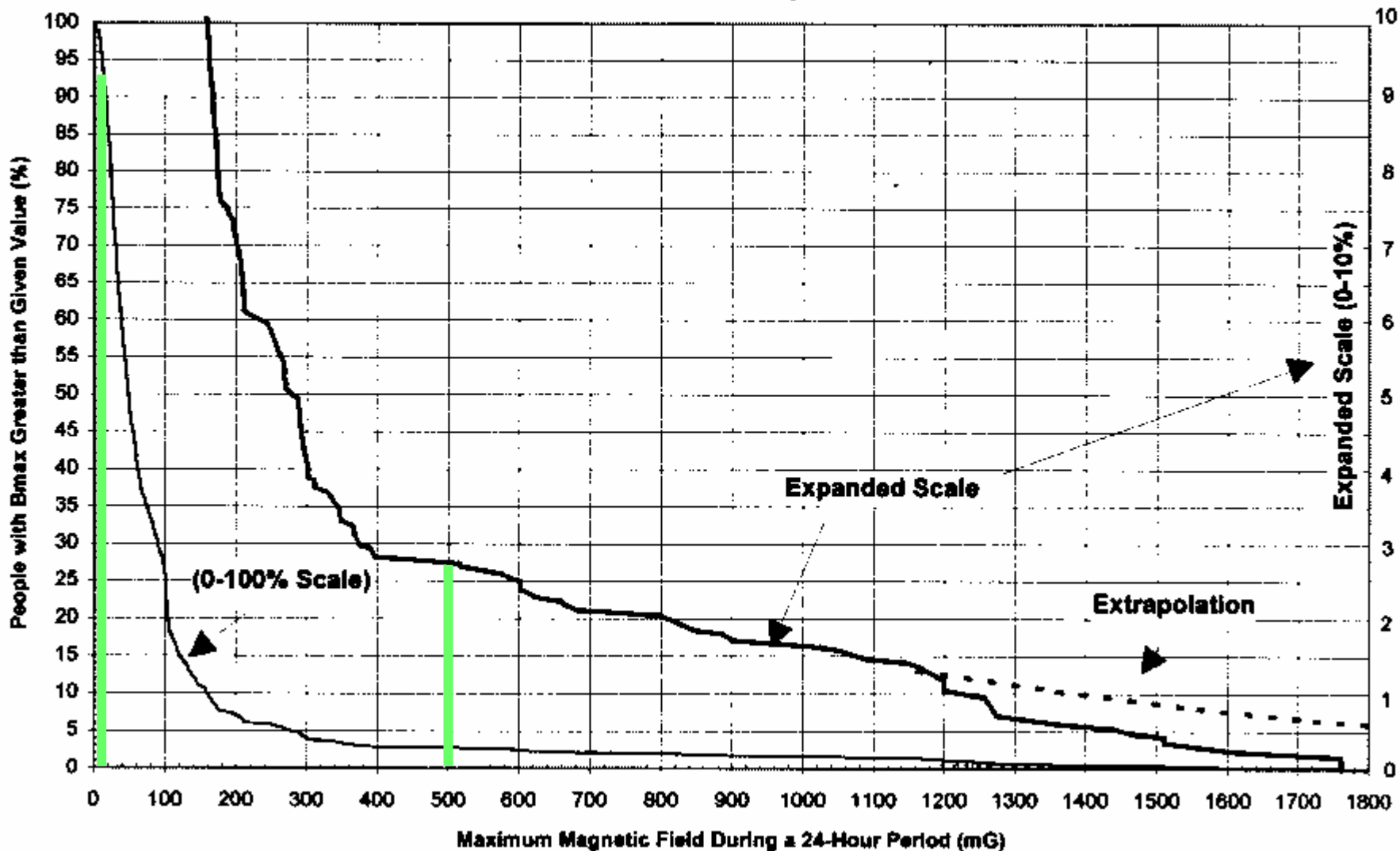


Estimated Distribution of 24-Hour Average Magnetic Fields and 95 % Confidence Interval

**Length of Time within a 24-Hour Period with Field Exceeding Specified Level
Estimates for the U.S. Population**



Estimated U.S. Population Distribution of Maximum Magnetic Fields During a 24-Hour Period

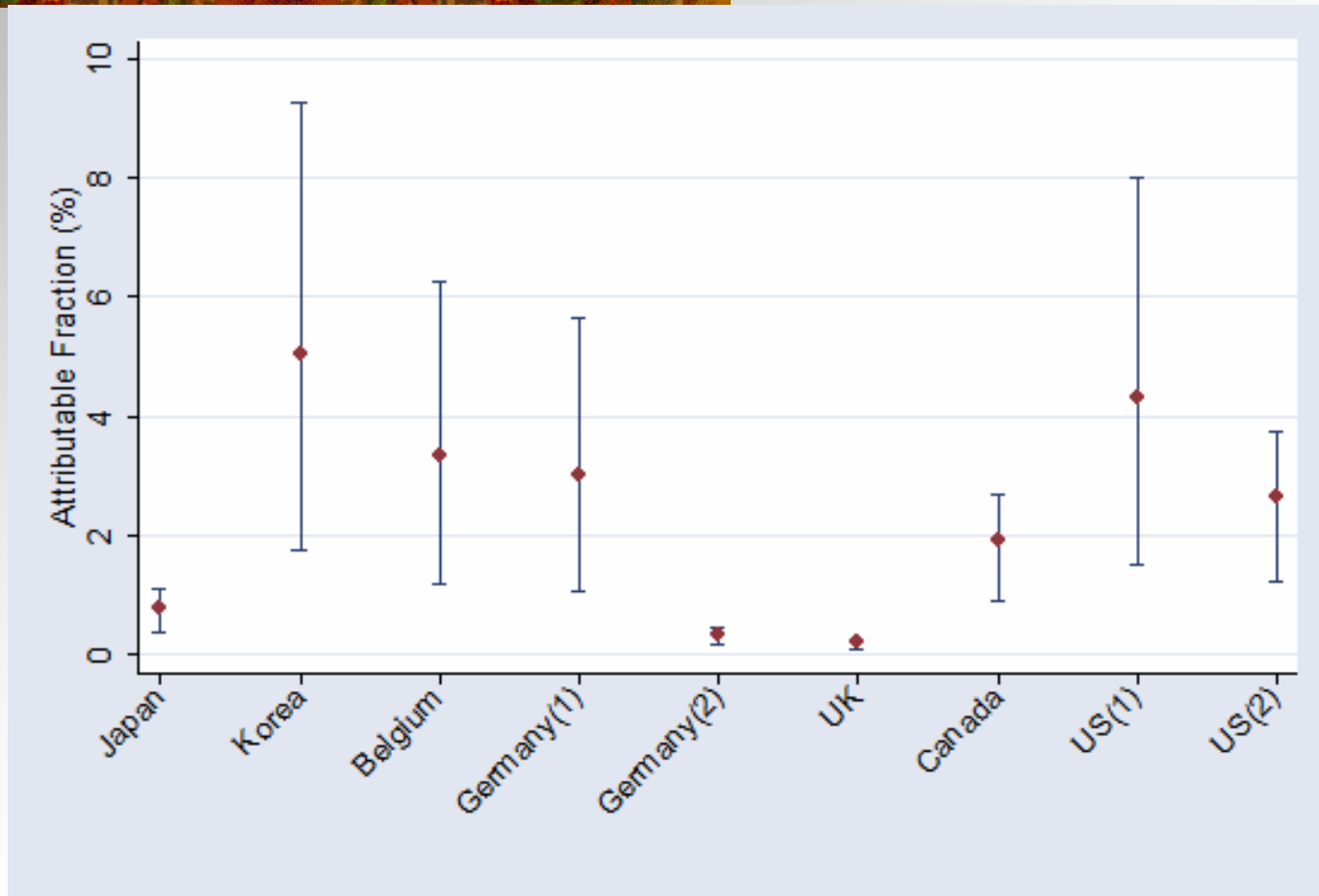


1.6 μ T
>90%

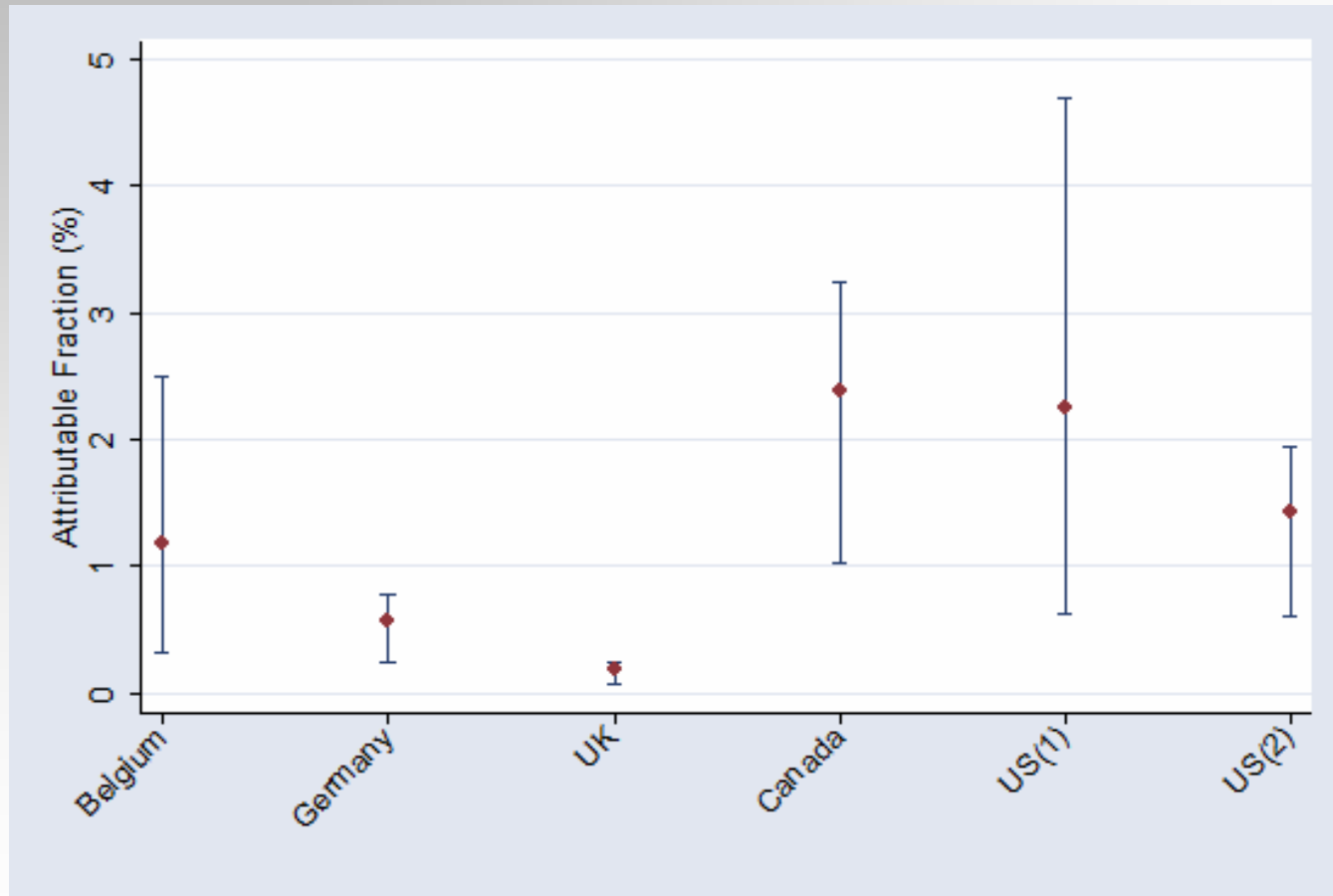
50 μ T
3%

From Zafanella Thousand Person Survey 1998
0.5 second sampling

Upper, lower and point estimates for attributable fractions, based on **arithmetic mean**



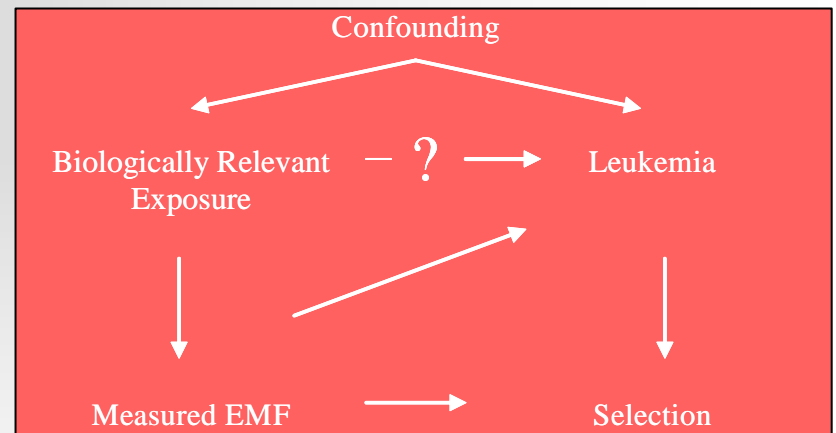
Upper, lower and point estimates for attributable fractions, based on **geometric mean**



Causality: Consistent association between childhood leukemia and exposure $> 0.3-0.4 \mu\text{T}$

Possible explanations:

- Chance????
- Misclassification???
- Confounding??
- Selection bias?
- Other?
- Causal relationship?



Causality and Magnitude of Risk: Multiple-Bias Modeling

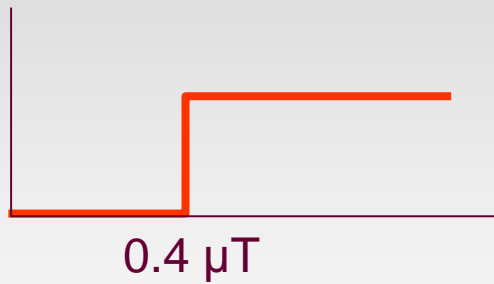
- Selection bias present, but unlikely to explain the association
- Confounding less important
- Misclassification leads to underestimate under most assumptions
- Probability that the combination of misclassification, selection bias, confounding and random error explain the association 2-4%

Causality other problems:

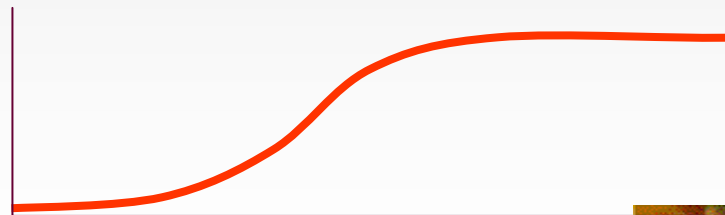
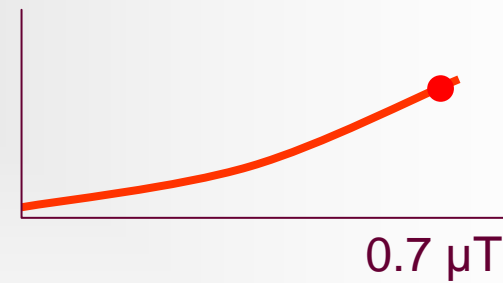
- Biophysical mechanisms: plausibility below 50 μT
- *In vitro* models: lack of robust and reproducible effect
- Lack of support from animal data

Shape of dose-response

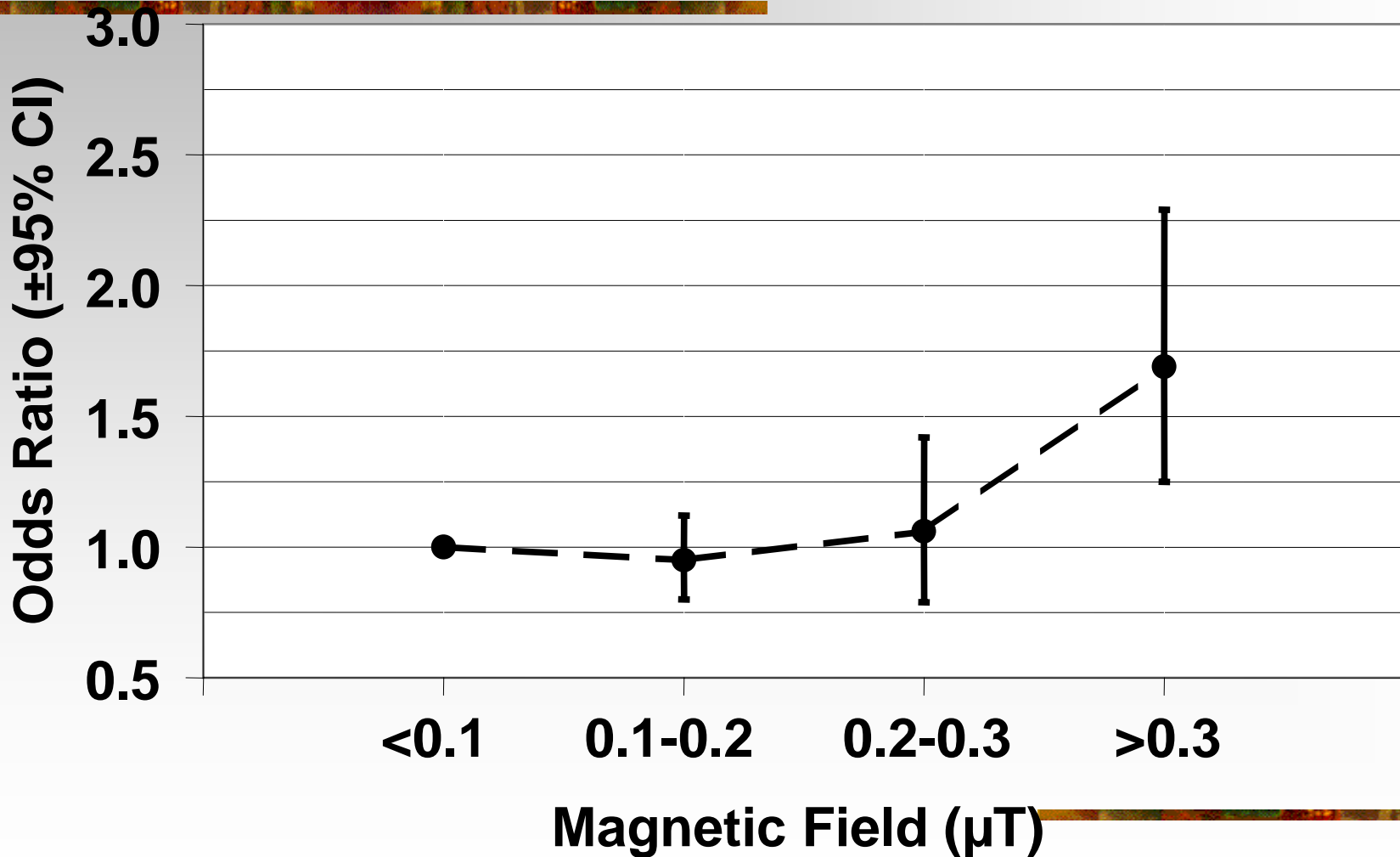
Biophysical plausibility
50 μT



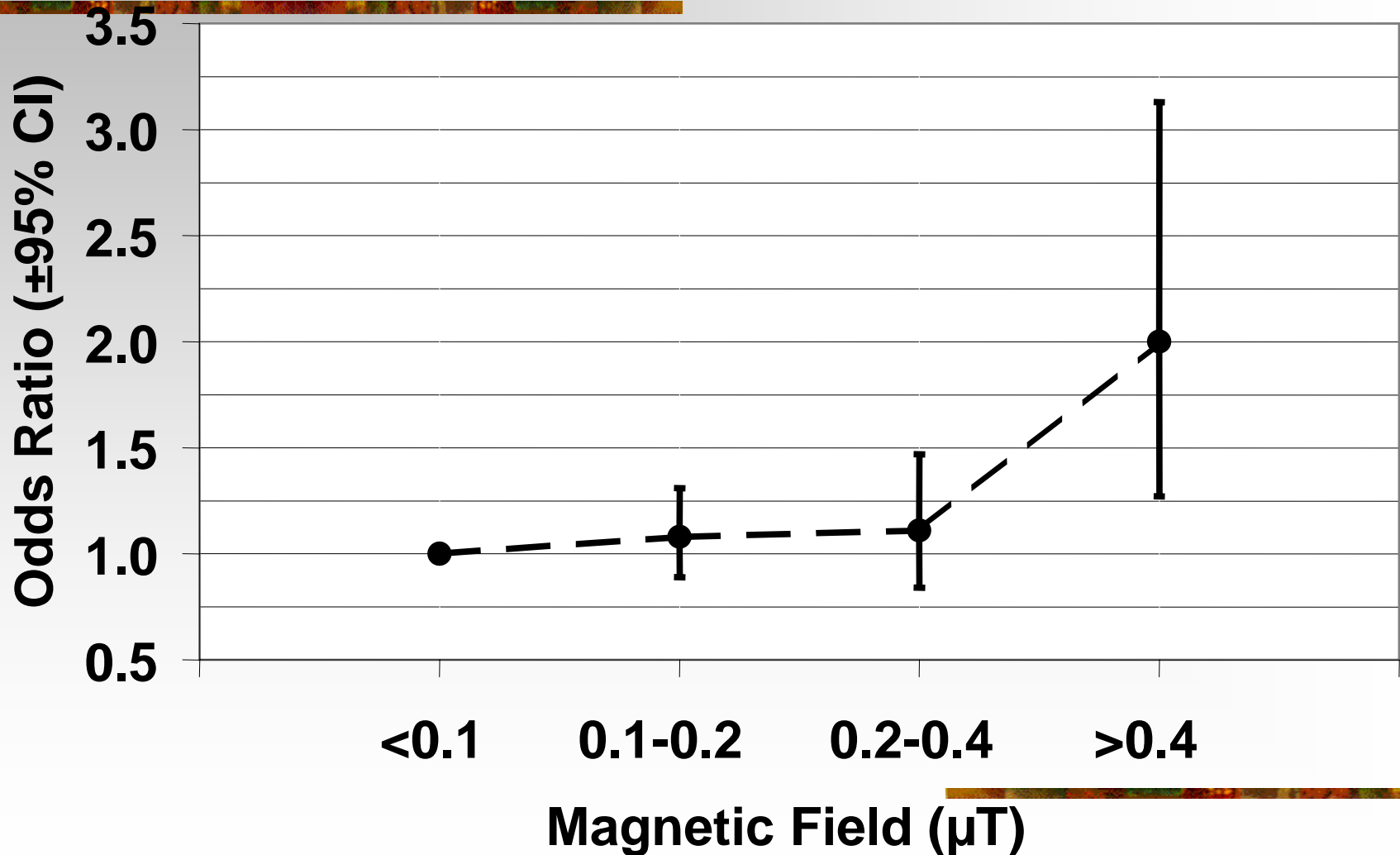
or



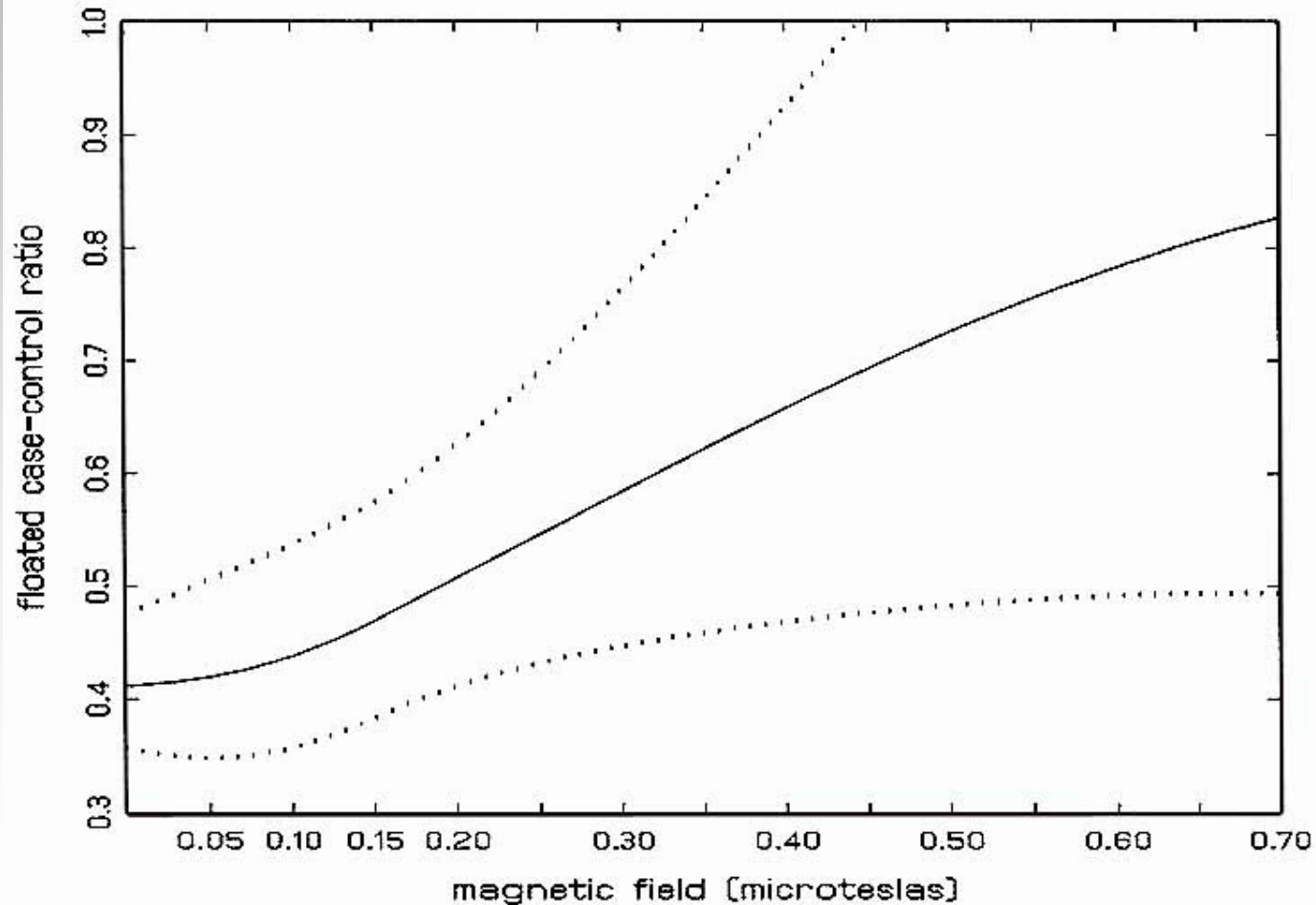
Result: Greenland et al., 2000



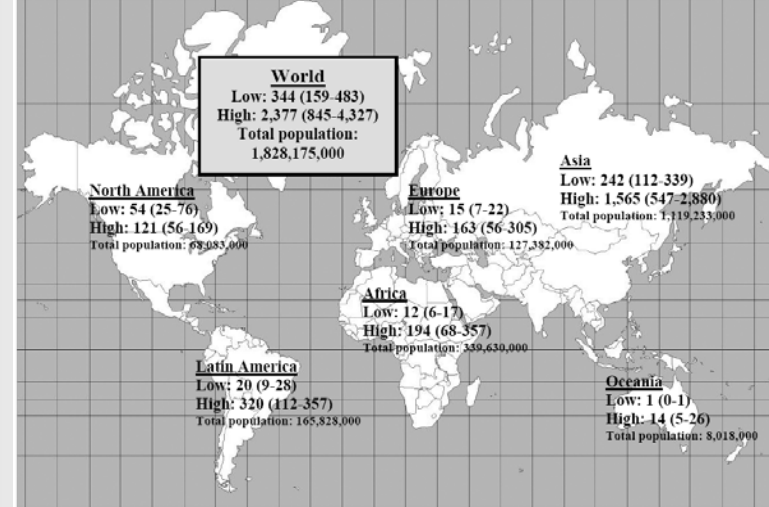
Result: Ahlbom et al., 2000



Floated Case-Control Ratio Based on the Spline Model (Greenland 1999)



Attributable Fraction



- Assuming a causal relationship, the fraction of childhood leukaemia cases attributable to ELF exposure across the globe appears to be small.
- World-wide, the number of cases possibly attributable to ELF exposure ranges from 100 to 2400.
- There are considerable uncertainties in these estimates, particularly in the assumptions regarding exposure distribution.

AF

- Even given a wide range of assumptions, the attributable fraction (AF) remains below 10%, with point estimates ranging from below 1% to about 4%.
- For small countries with low exposure, the number of attributable cases is less than one extra case per year. World-wide, the range is from 100 to 2000 cases possibly attributable to ELF exposure.
- The fraction of childhood leukemia cases attributable to ELF exposure across the globe appears to be limited. There remain, however, a number of uncertainties in these AF estimates, particularly in the exposure distributions.

- No pattern of differences among the study results was noted (homogeneity $P = 0.29$);
- in particular, no pattern of results related to measurement method was detected.
- which if any method might be more accurate for the target exposure.
- The latter target is itself is unknown; it is here taken to be lifetime arithmetic average field.
- in contrast to the conventional results, no effect remains a fair possibility under our posterior analysis as well as under more skeptical analyses.

Uncertainty Analysis

- Formal analyses accounting for uncertainties about study biases as well as uncertainties about exposure distribution
- These analyses support the idea that the public-health impact of residential fields is likely to be limited, but both no impact and a large impact remain possibilities in light of the available data
- The difference between the two analyses varies in both directions, but on the whole the Bayesian results make the conventional results look overoptimistic and overconfident

Some comments...

- Some crucial data missing (e.g. prevalence of exposure in different countries)
- Looking at various analyses, assumptions, modeling conclusions are fairly robust
- Nevertheless due to large uncertainties AF numbers should be used at best as a best guess

Interpretations for policy development

- Not proven – no need for action (Someofyou et al. 2004)
- Low/no cost PP based on childhood leukemia (Kheifets et al. 2005)
- Enough evidence for 0.2 μT limit (Kundi et al. 2006)
- Extrapolation from tox leads to 10 μT Limit (Valberg 2006)
- Other outcomes (adult leukemia, brain, ALS, miscarriage) need to be considered thus much larger expense justifiable under PP (Henshaw et al. 2007)

Are we prepared to say...

- Reducing exposure is good?
- For the individual:
 - concentrate on removing peaks?
 - concentrate on background fields?
- For the population:
 - concentrate on removing $>0.4 \mu\text{T}$?
 - concentrate on reducing average?

Protective measures

Conclusions:



- It is essential that guidelines are developed in order to protect against the established adverse effects
- Because there are remaining uncertainties as to the overall health impact of ELF, the use of precautionary approaches is warranted.



Protective measures

Conclusions:

- It is essential that guidelines are developed in order to protect against the established adverse effects
- Because there are remaining uncertainties as to the overall health impact of ELF, the use of precautionary approaches is warranted.
- Given the weakness of the evidence concerning childhood leukaemia and the limited impact on public health, the benefits of exposure reduction are unclear and the costs to reduce exposure should be very low.



Protective measures: Recommendations i

Acute effects:

- Policy makers should establish guidelines
- Establish a protection program that includes measurements of all sources to ensure that the guideline limits are not exceeded



Protective measures: Recommendations ii

Chronic Effects:

- Provided there is no compromise to health, social and economic benefits of electric power, implementing very low cost precautionary procedures to reduce exposures, is reasonable and warranted
- Measures that involve very low cost changes to engineering practice to reduce ELF exposures from equipment or devices should be considered.



Protective measures: Recommendations iii

Chronic Effects:

- Local authorities should enforce wiring regulations to reduce unintentional ground currents but proactive measures would be expensive and unlikely to be justified
- Local planning should be improved to include better consultation between stakeholders when siting major EMF emitting sources
- Government and industry should promote research programs to reduce uncertainty

